The Use of Remote Sensing and GIS Techniques to Detect Land Use/Cover Transfers in the Ejisu Municipality of Ghana

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Abstract

Available information on land use/cover transfer is at the global and national levels while change processes are widespread at the local level. Natural resources monitoring and assessment programmes in Ghana focus on maintenance of quality, quantity of merchantable species and diversity of forest resources. However, there is the need to detect land use/cover transfer information in Ghana at all levels of aggregation for proper management of forest resources. Thus this study sought to identify the prevalent land use/cover transfer and to link them to socio-economic factors driving them at the local level using remote sensing and GIS techniques in a forestry context of Ejisu municipality. To achieve this, post classification change detection was conducted between two years using Landsat TM 1986 and ETM 2010 to detect changes/transfers at the municipal level to produce a transfer matrix and transfer map of the two years. Fragment statistics including number of patches, largest patch index, patch density, mean patch size were computed. The analysis of the change revealed that forest area has decreased from 18628.588 ha in 1986 to 4784.484 ha in 2010 due to transfer to grass indirectly via agriculture. Forest fragmentation also decreased in 2010.

1. Introduction

National monitoring and assessment programmes of focus on maintenance of quality, quality of merchantable species and diversity of forest resources in the forest reserves (Lillesand and Kiefer, 1994) and off reserves with less attention on land use/cover transfers taking place. The available information is at the global and national levels while land use/cover change is widespread at the local level (Kumi-Boateng *et al*, 2010). It is important to note that detection and measurement of change depends on spatial scale and thus, the higher the spatial level of detail, the larger the changes in the areal extent of land use/cover which can be detected and recorded (Sader and Hayes 2001). However, changes/transfers occurring in the environment and the ecosystem structure have aroused worldwide concern due to their influence on climate, sea level, the global fluid system and the atmosphere (Meyer and Turner II, 1992). Like many other developing countries, Ghana is not an exception to land use/cover transfer problems. Ghana's economy depends largely on its natural resources especially its forests. Important products like fuel wood, timber, wildlife and fruits are obtained from the forests. The forests provide conditions which are conducive for the production of cash crops like cocoa and coffee. Monitoring and assessing the quality and quantity of the marketable products of the forest resource should be much focus on the current land use/cover transfers taking place. Land use/cover transfer can be induced either naturally or by human activities in the environment. One important change factor within the Ghanaian landscape is deforestation (Kumi-Boateng *et al*, 2010). Deforestation begins with gradual depletion of the forest by logging, agricultural activities, mining, fuel wood collection and wildfires. Other change factors which affect the land use/cover include forest degradation, flooding, population increase and urbanization.

The Ejisu municipality off reserve area of Ghana, which is an important source of economic timber species and a range of biodiversity, has been plunged into a rapid land use/cover transfers. These transfers consist mainly of rain-fed agriculture usually with mixed cropping of maize, cassava, cocoyam and plantain for subsistence and commercial purposes; abandoned fallow lands made of grass, forest patches, settlement areas and cocoa plantation. The resulting land use/cover transfers are mainly from forest to settlement areas, food crop farms and plantation farms. These changes/transfers in use and in cover have rendered the Ejisu off reserve areas patchy with bush fallow and marshy grasslands interspersed with farmlands. However, very little is known about the amount of transfers occurring in terms of the areal extent. Again, the protected permanent forest estate that boarders the off-reserves have also come under pressure from non-timber forest product collectors and illegal chainsaw operation since these products are not available in the outside reserve areas of the Ejisu municipality. Land use/cover transfer is the key to many diverse applications such as environmental, forestry, hydrology, agriculture and geology (Kumi-Boateng *et al*, 2010). Hence, reliable information on land use/cover transfer is required for the monitoring and assessment of vegetation condition as well as the process of land use/cover change by the forest and land managers. It is in line with this that this paper seeks to detect the prevalent land use/cover transfers and to establish the socio-economic factors driving them using remote sensing and GIS techniques.

2. The Study Area

The relevant information about the study area is discussed in the following subsections.

2.1.1 Location and Size

The study area is one of the 27 administrative and political districts in the Ashanti Region of Ghana. The Ejisu Municipality stretches over an area of 637.4 square kilometres constituting about 10% of the entire Ashanti Region and with Ejisu as its capital which is located 20 m away from Kumasi. Its population stood at 124 176 as at 2000 (Anon, 2003). Currently it has four urban settlements namely, Ejisu, Juaben, Besease and Bonwire. The Municipality is located in the central part of the Ashanti Region and provides enormous opportunity for creating an inland port for Ghana to serve northern section of the country. It lies within Latitude 1° 15' N and 1 ° 45' N and Longitude 6° 15' W and 7° 00' W. Ejisu Municipality shares boundaries with six (6) other Districts in the Region. To the North East and North West of the Municipality are Sekyere East and Kwabre East Districts respectively, to the South are Bosomtwe and Asante-Akim South Districts, to the East is the Asante-Akim North Municipal and to the West is the Kumasi Metropolitan (Anon, 2010). This study focuses on the northern portion of the municipality. It is currently going through rapid landscape transformation because of the proximity to a more densely populated and expanding Kumasi Metropolis.

2.1.2 Climate

Climate as is the case for most of the middle belt in Ghana, the Municipality experiences tropical rainfall that is bi-modal rainfall pattern and wet semi-equatorial climate (Anon, 2010). It is characterized by double maxima rainfall lasting from March to July and again from September and normally ends in the latter part of November. The mean annual rainfall is 1200 mm which is ideal for minor season cropping (Anon, 2010). Temperature ranges between 20°C in August and 32°C in March. Relative humidity is fairly moderate but quite high during rainy seasons and early mornings.

2.1.3 Vegetation

The Municipality lies within the semi-deciduous forest zone which does not differ much in appearance from the Rain Forest zone (Anon, 2010). The fair distribution of temperature and rainfall patterns enhances the cultivation of many food and cash crops throughout the Municipality thus making the Municipality a food sufficient area in Ghana. The forest reserve serves the purpose of both production and conservation. The Bobiri forest reserve is floristically diverse and endowed with large quantities of economic timber and also very rich in biodiversity. Most of the trees shed their leaves during the dry season, but not at the same time for all the trees of the same species. The off reserve areas are unsustainably logged by illegal and legal loggers and mainly consist of annual cops, cash crops and fallow lands along the rivers and streams (Anon, 2010).
The ecologically unfriendly farming practices, stone quarrying activities and illegal chain saw operations have resulted in the natural vegetation cover being degraded into a secondary forest. Massive deforestation has occurred in areas such as Ejisu, Adadientem, Achiase and Peminase, resulting in the forest giving way gradually to savanna conditions (Anon, 2010).

2.1.4 Geology and Soil

The geology and soils types in the Municipality offer vast opportunity for the cultivation of traditional and non-traditional cash crops and other staple food stuff and thus presents the Municipality as one of the food basket case in Ghana. The Municipality falls within the forest dissected plateau terrain region. This region is underlain by the pre-cambrian rocks of the Birimian and Tarkwaian formations. The area rises from about 240 metres to 300 metres above sea level. The topography is generally undulating and is drained by a number of rivers, notable among them being Oda, Anum, Waropong, Bankro, Hwere, Bediwaa and Baffoe (Anon, 2010). In the rainy season, occasional flooding is experienced in the inland valleys along the river basins. There are eight soil types in the municipality. These are the granite based Kumasi–Offin Compound, Bomso–Offin

Compound and Swedru-Nsaba Simple Association; Birimian rock based Bekwai-Oda Compound, Kobeada-Eschiem-Sobenso-Oda Complex and Atunkrom-Asikuma Association; Tarkwaian based Juaso-Mawso Association and lastly the superficial deposits based Boamang-Suko Simple Association (Gaespenu *et al*., 1996). All these soil types support some form of agriculture ranging from annual crops to cash crops.

3. Data Acquisition And Processing

Data source, collection and processing as well as the software used are discussed in the following subsections.

3.1.1 Data Source

The data used for the study was based on two time series Landsat satellite imageries of 1986 and 2010. The 1986 image was Landsat TM and that of the 2010 Landsat ETM plus. They were obtained from the global land cover database. A 1:50 000 topographic map from the Survey Department of Ghana was used as a guide for the field navigation to pick the ground control points for the geo-referencing, classification and accuracy assessment.

3.1.2 Software Used

The software used for the image geo-reference, classification and accuracy assessment were Erdas Imagine 9x, ArcGIS 9x, Fragstats 3x and R2.4.

3.1.3 Data Processing

The flowchart shown here (Figure 1) indicates the methods applied in detecting the land use/cover transfers within the Ejisu municipality.

3.1.4 Image Preprocessing

The 1986 and the 2010 images were re-sampled to 25 x 25 metre pixel size using the nearest neighbour re-sampling method to preserve the original image radiometry. The nearest neighbour re-sampling method assigns the digital number (DN) value of the closest original pixel to the new pixel without being changed and retains all spectral information, which makes the re-sampled image efficient in the classification. The images were originally in the global coordinates, UTM zone 30/WGS 84 and thus were geo-referenced to the local coordinate system; traverse mercator projection in the legion datum. A total of 30 ground control points (GCPs) were picked at road intersections and river confluence from the topographic map and the 1986 images to determine the transformation coefficients using 2nd order polynomial transformation.

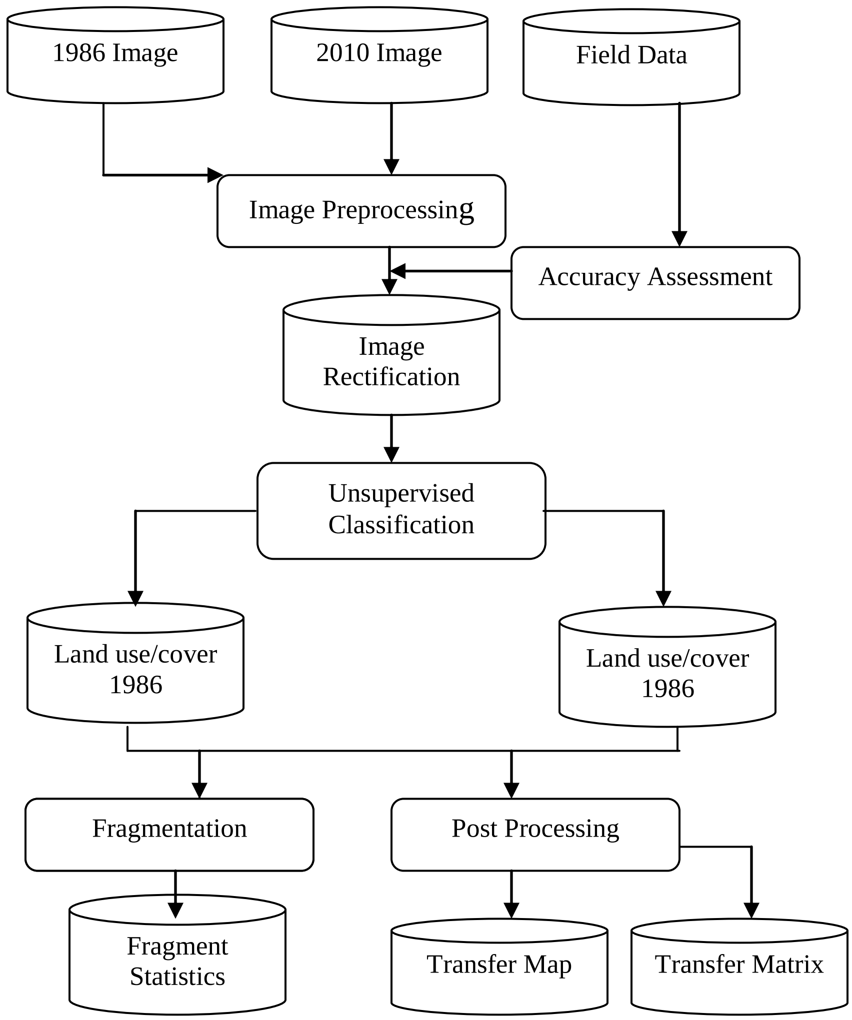

Figure 1 Work flow of land use/cover transfer delineation

The 2010 image was then co-registered to the geo-referenced 1986 image. The total root mean square error for the geo-referenced processes positional accuracy was 8.42 m which is 0.4 of a pixel. The error margin was acceptable since it is within a pixel.

3.1.5 Image Classification

In this study, both images were classified into a 50 spectral classes each using the ISODATA algorithm of Erdas Imagine 9x to perform unsupervised classification. The TM 1986 and ETM 2010 images were aggregated into 6 major land use/cover types. The field points and their respective cover types were used for the class identification and validation during the aggregation procedure for the ETM 2010. The TM 1986 lacked reference points hence its aggregation was based on cover types in 2010 which are likely not to have changed and the views of farmers. The use of field points in the class identification introduced elements of supervised classification. The main land use/cover classes considered include forest, fallow land, agriculture land, bamboo-raffia complex, grass and build up areas (Table 1). The accuracy of the classified ETM 2010 image was assessed using 95 reference points to obtain error matrix and kappa statistics.

Table 1 Main land use/cover classes in the Ejisu municipality

LAND USE/COVER	DESCRIPTION
Forest	Moist semi-deciduous forest and areas with high tree cover density reaching 15 m
Fallow	Land which has been logged or cultivated in the past and now left to recover. It consist of shrubs and trees reaching between 2 m and 15 m
Agriculture	Land under cultivation such as annual cropping, cocoa and oil palm plantations
Bamboo-raffia	Predominately *Bambusa*, *vulgaris* and raffia palm mixture found along water ways and marshy areas
Grass	All forms of grass ranging from creeping species up to tall elephant grass
Build-up/bare	Areas with high intensity of infrastructure and land areas of exposed soil surface

3.1.6 Detecting Changes

The classified maps of TM 1986 and ETM 2010 were loaded in the matrix dialogue of Erdas Imagine 9x to indicate changes between the images in the form of change map. The change matrix derived from raster attributes of the change map revealed the class –to-class transitions observed between 1986 and 2010. The major limitation of the change detection conducted in the study is that the accuracy of the change detection can not be accounted for due to lack of reference data to assess the accuracy of the TM 1986 image.

3.1.7 Fragmentation Analysis

The statistical analysis was mainly fragmentation analysis. Fragmentation analysis were applied to interpret the impact of land use/cover transfers within the landscape by calculating for some elements of the land use/cover class of interest (forest) a range of spatial metrics to describe fragmentation and spatial distribution pattern in the study area. Fragstat 3x is a spatial pattern analysis program for thematic maps which quantifies the areal extent and spatial distribution of patches (i.e. polygons on map coverage) within a landscape (Turner, 1989). The fragmentation analysis was achieved at two levels namely; whole study area level for both 1986 and 2010 images to compare and assess changes in the fragmentation due to land use/cover transfers and also in a hotspot level to assess the dynamics of forest transfers. At the whole study area level, which is of interest in this research, metrics like number of patches, largest patch index, patch density and mean patch size were computed.

4. Results And Discussions

The results of the study are discussed in the following subsections.

4.1.1 Results

Land use/cover classification

The unsupervised classification method employed in this study yielded two land use/cover maps from the 1986 and 2010 Landsat images. The maps categorized the area into six main land use/cover classes as shown in table 1. The classified land use/cover maps of the Ejisu municipality are shown in figures 2 and 3.

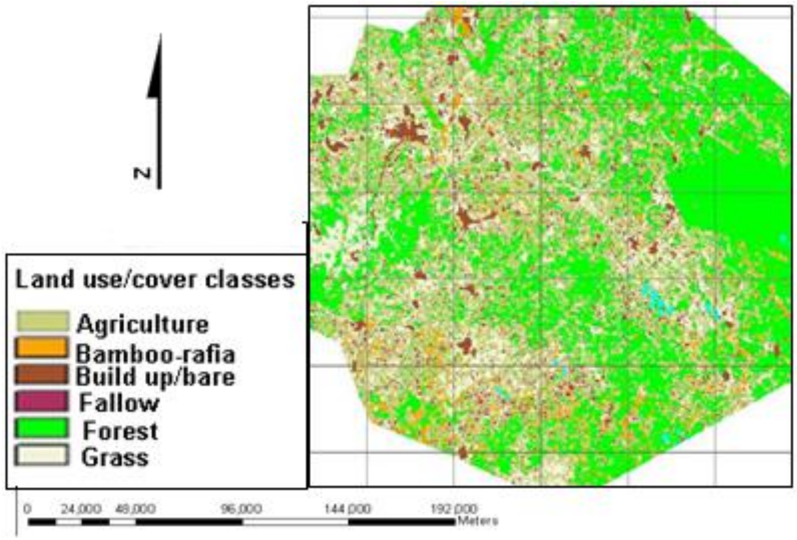

Figure 2 Land use/cover map of Ejisu Municipality, 1986

In the 1986 land use/cover map above, forest is mainly found in the north-eastern and south eastern portions of the area with very few patches scattered across the entire area. Agriculture and grass are predominately in the western part and around settlements while the others are scattered across the landscape with bamboo-raffia restricted to marshy areas along river courses. Table 2 reveals that agriculture, forest and grass form the major land use/cover in the study area occupying 33.32%, 23.43% and 17.88% of the area respectively in 1986. It is followed by bamboo-raffia (9.27%), fallow (8.85%) and build-up/bare (7.25%).

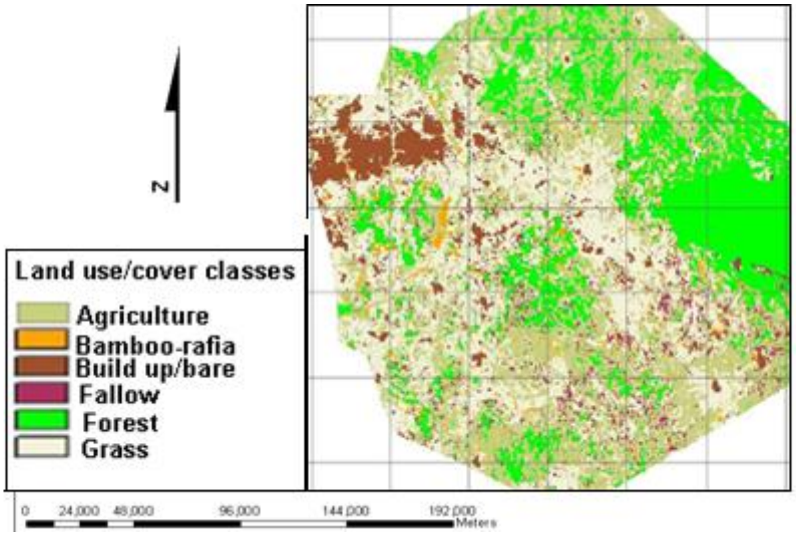

Figure 3 Land use/cover map of Ejisu Municipality, 2010

In the 2010 land use/cover map (Figure 3), forest is found in patches mainly in the north and central portions; however, there is a large homogenous patch of forest reserve in the north-eastern part of the study area. Agriculture spreads across the entire landscape but the middle and parts of the southern portions has been taken over by grass. Fallow is scattered among agriculture, build-up/bare and is also predominate in the north-western corner of the study area. The year 2010 experienced a redistribution of the class areas as shown in table 2.

Table 2 Land use/cover classes and their areas for 1986 and 2010

Land use/cover	**1986**		**2010**	
	Area (ha)	**(%)**	**Area (ha)**	**(%)**
Forest	18628.589	23.43	4784.848	6.02
Fallow	7034.5456	8.85	5699.856	7.17
Agriculture	26491.954	33.32	30736.845	38.66
Bamboo-raffia	7372.6556	9.27	4763.929	5.99
Grass	14211.364	17.88	27520.942	34.62
Build-up	5763.1936	7.25	5995.878	7.54
Total	**79502.300**	100.00	**79502.300**	100.00

Agriculture, grass and build-up forms the major land use/cover (Figure 4) for the year 2010 occupying 38.66%, 34.62% and 7.54% of the area under study respectively. This is followed by build-up/bare (7.54%), fallow (7.17%), forest (6.02%) and bamboo-raffia (5.99%).

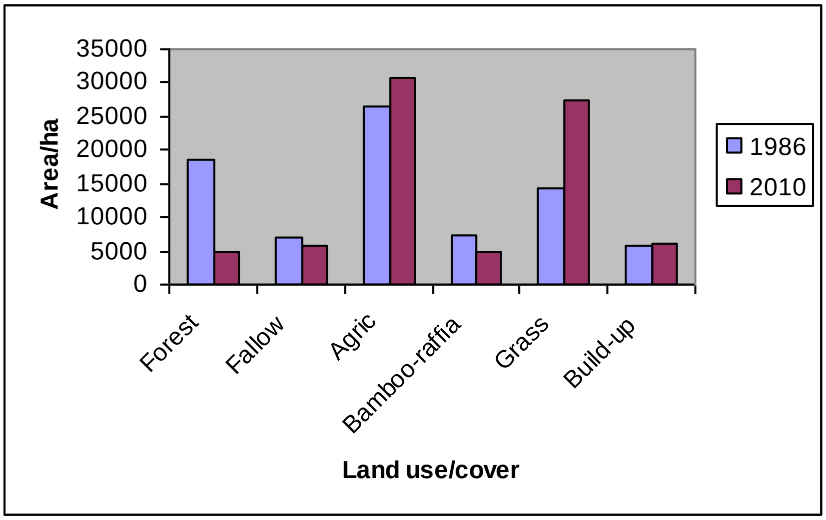

Figure 4 Ejisu Municipality land use/cover distribution from 1986-2010

Classification Accuracy

The 2010 land use/cover map yielded an overall accuracy of 89.76% when the classified image was compared on a class by class basis with 95 transformed field data in the confusion matrix. In order to estimate the level of significance, kappa statistic was conducted and this came out to be 0.83 as the overall significant level. The accuracy of the 1986 classification could not be reported since there were no field reference data.

Land use/cover Transfers

The comparison between the 1986 and 2010 land use/cover maps revealed various degrees of changes in the area resulting from multiple transfers of land use/cover classes. The graph in figure 5 shows the extent of transfers among the land use/cover classes. Generally all the six classes experienced some form of transfer in size from 1986 to 2010. Figures 4 and 5 depict that forest, fallow and bamboo-raffia decreased in areal extent where as grass, agriculture and build-up/bare increased over the 24 year period under study. During the period of study, forest and grass experienced the most negative and positive changes respectively in the Ejisu municipality. While forest lost a substantial area of 13843 ha, grass increased by an area of 13309 ha.

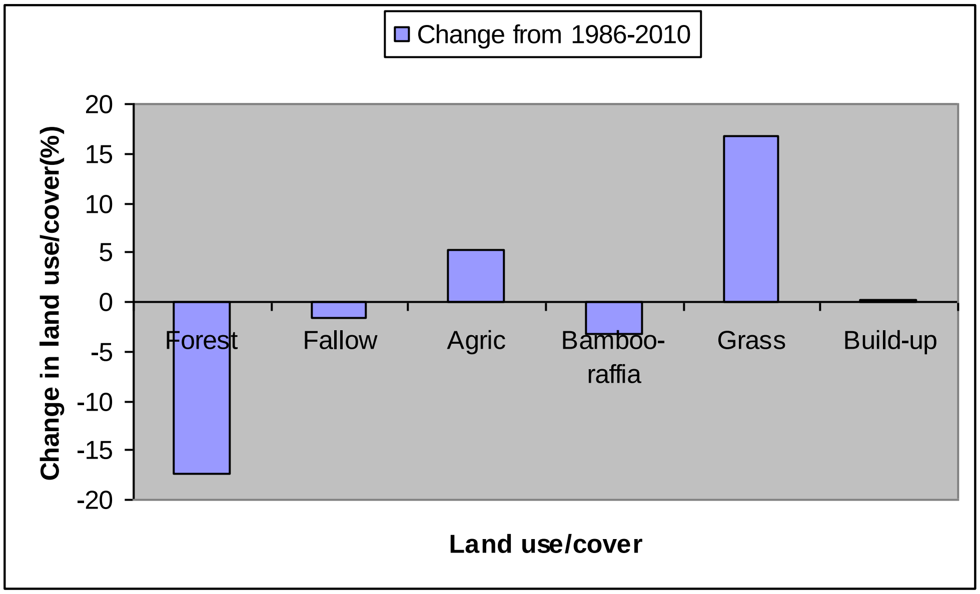

Figure 5 Contribution of individual land use/cover to the total change

Land use/cover Transfer Map

The landscape of Ejisu municipality has been transformed through complex transfer of areas under a particular land use/cover in 1986 to another in 2010 as shown in figure 6.

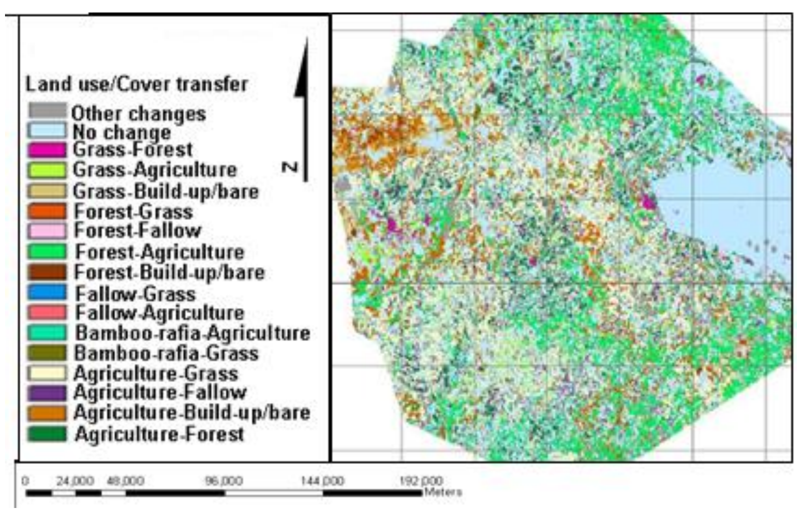

Figure 6 Major land use/cover transfer in Ejisu Municipality, 1986-2010

The diagonal of table 3 shows that the proportion of the landscape that remained stable is 24%. Build-up/bare experienced the highest persistence while agriculture had the least among man made classes. Fallow emerged highly persistent and bamboo-raffia the least when compared with other natural vegetation classes. With a transfer of 9370.696 ha, agriculture made the single highest transfer to grass. However, the reverse transfer for the period was about half lower though substantial in the order of transfers. This large transfer to grass almost paid by transfer of forest to agriculture constituting 9290.079 ha. Nevertheless grass is also receiving immensely from forest (5426.455 ha). The reverse transfer to forest from both agriculture and grass are not enough to equate the loss. Transfers from agriculture to fallow and the reverse are marginally different. Apart from grass which received 2042.212 ha from build-up/bare all transfers from this class are the least in all classes however it is making substantial gains from grass (1338.001 ha) and agriculture (1422.260 ha). Bamboo-raffia transfer to fallow is 794.387 ha yet receives unsubstantial amount of 52.540 ha in return.

Table 3 Land use/cover transfer matrix of Ejisu municipality between 1986 and 2010

Land use/cover (1986)	**Land use/cover (2010)**						
	Forest	**Fallow**	**Agric**	**Bamboo**	**Grass**	**Build-up**	**Total(1986)**
Forest	**1063.403**	1493.222	9290.079	548.153	5426.455	807.275	18628.588
Fallow	750.117	**703.161**	2613.788	52.540	2319.227	595.712	7034.546
Agric	990.059	1627.043	**9647.933**	3433.962	9370.696	1422.260	26491.954
Bamboo	725.760	794.387	2699.654	**261.459**	2334.827	556.568	7372.656
Grass	771.839	961.420	4659.185	453.391	**6027.527**	1338.001	14211.364
Build-up	483.668	120.622	1826.206	14.424	2042.212	**1276.061**	5763.194
Total(2010)	4784.848	5699.856	30736.845	4763.929	27520.942	5995.878	***79502.29932**

(Shaded cell is the total area under study)*

Fragmentation at the whole study level

The study area has undergone changes in pattern over the 24 year period. There has been a general reduction in the number of patches of forest and other land use/cover from 1986 to 2010. However, from 3411 to 1105 patches (Table 4), forest had more fragments in both years than other land use/cover patches. Forest recorded lower LPI compared with other land use/cover for both years. LPI of forest declined by 2.71% between the two years whiles that of the other land use/cover appreciated by 14.97%. PD of forest follows a similar trend like forest LPI but other land use/cover was different from its LPI.

Table 4 Patch statistics at the whole study area

PATCH INDICATOR	**1986**	**2010**
Number of Patches (NP)		
Forest	3411	1105
Other land use/cover	1049	595
Large Patch Index (LPI)/%		
Forest	8.71	6.00
Other land use/cover	20.48	35.45
Mean Patch Size (MN)/ha		
Forest	3.52	5.06
Other land use/cover	12.34	51.67
Patch Density (PD)		
Forest	3.78	2.3
Other land use/cover	2.02	0.76

4.1.2 Discussions

Land use/cover maps of Ejisu municipality

The classified images of 1986 and 2010 were key tools in the monitoring of land use/cover transfers in the Ejisu municipality. Image classification is never a complete process when the accuracy of the output land use/cover map is unknown (Kumi et al, 2010). The quality of the classification is judged by its accuracy. The 89.76% overall accuracy recorded for the classification of the 2010 ETM image into the six major classes of the study area was higher than the 85% standard noted by Campbel (2002). Further analysis with kappa statistic revealed that 83% of the whole classification was in agreement with the reference data used for the assessment leaving the remaining 17% to chance. Nothing could be reported on the accuracy of the 1986 image due to the unavailability of validated map or aerial photo of the study area for that period. The classified image of 1986 is as good as the 2010 image since the reference data used to assign class on it were invariant areas on the 2010 image.

Land use/cover transfers and fragmentation analysis

Detail information on classes making transfers, by how much and the proportion gained in return is the main advantage of the post classification change detection method used in the study. The change detection yielded a land use/cover map showing the spatial distribution of transfer in the classes (Figure 6) and the change matrix (Table 3) indicates the proportions of specific land use/cover taking part in the transfers. The Ejisu municipality landscape has experienced complex land use/cover transfers resulting from increased human activities over the 24 year period under study. Land use/cover transfers have compositional and structural implications on the landscape. Structurally, the general reduction in the number of patches in forest and other lands between both years indicate a reduction in fragmentation in the study area. The reverse indication suggested by higher largest patch index of 1986 is likely due to the large patch size portrayed by Bobiri forest reserve and the adjoining off-reserve forest areas, which in 200 had lost some connections and areas with and in the off-reserves respectively. However, the smaller mean patch size and the higher percentage in patch density of 1986 forest than 2010 forest is a clear indication of reduced fragmentation of forest in 2010. All the indexes point to the fact that other land in 1986 is more fragmented than 2010. the high mean patch size of both forest and other lands in 2010 indicates that most of the patches were getting bigger due to aggregation experienced by other lands in comparison with forest clearly indicates that small patches of forest usually bordering agricultural fields are being replaced by other lands in 2010. The unusual indication of increased forest size suggested by the mean size index could be large patch size contributed by Bobiri forest reserve in the computation of the index. Land use/cover transfers impacting the landscape structure have resulted in more than 100% increase in both grasslands build-up/bare areas and decrease in forest and agriculture. Forest are significantly transferred to agriculture and grass while agriculture is interestingly losing a little more than the gain from forest to grass. The inference drawn from the nature of transfer is that though forest transfer to agriculture is substantial, agriculture is only acting as a transit point to grass. This may be so because agriculture decreased and forests are not cleared to favour grass since ranching is not a land use option in the area. This explains why generally agricultural lands reduce irrespective of the gains made from bamboo-raffia and forest. Also agriculture and grasslands formerly surrounding towns contribute the majority of the transfers to build-up/bare with a gain exceeding 100%. Underlying these trends is an important socio-economic factor or issue. Urban to peri-urban migration which is a predominant factor in the study is claiming agriculture lands close to urbanized areas and dislocated farmers seeks new agriculture lands at the expense of forest lands in areas beyond urbanization. The increase in build-up area is concentrated at the boundary between the municipality and Kumasi radiating from the sides of the Kumasi-Accra road. This is due to the spilling effects from the rapid expansion of Kumasi. The nature of the urban expansion along the Kumasi-Accra road is rather relatively linear in nature. Although the economy is gradually changing to commensurate the urbanization, farmers who have lost farmlands to urbanization process seek new lands further away from Kumasi on lease. Consequently, pressure is mounted on the land resource in these new areas resulting in additional forest clearance and continuous cropping. Another reason for the large transfer of forest is the gradual replacement of old cocoa (require tree shade) with the high yielding hybrid (no shade requirement) and the shift to non traditional crops like citrus plantations that grows best without trees. In addition illegal logging by both farmers and commercial groups play key roles in reducing the forest cover of Ejisu municipality.

5. Conclusion

This study has used remote sensing and GIS techniques to monitor land use/cover transfers especially for forest in the study area. In Ghana forest transfer monitoring are conducted at the national or administrative level and the general results used as a reference to prescribe counter measures. Remote sensing observations revealed that landscape of Ejisu municipality has significantly been transformed through large amounts of forest transfers between 1986 and 2010. The technique has provided an easy way to zoom in specific areas in a landscape that needs critical attention. Statistical analysis on the fragments in the whole study area differs. With a transfer of 9370.696 ha, agriculture made the most single highest transfer to grass. This piece of information generated by the study is beneficial to the forest and land managers for better planning.

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